Searches for Physics Beyond the Standard Model at CDF

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Lake Louise Winter Institute
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Outline

- Only CDF new results: L ~ 2 fb^{-1}
- SUSY searches:
  - $\tilde{g}/\tilde{q}$ inclusive production
  - $\tilde{\chi}_2^0\tilde{\chi}_1^\pm$ trilepton production
  - $B_s \rightarrow \mu^+\mu^-$
- Extra-dimension and signature based searches:
  - $\gamma\gamma + \not\!\!E_T$ and $\gamma\gamma + \tau$
  - $\gamma + \not\!\!E_T$ and jet + $\not\!\!E_T$
  - di-jet resonances

✓ see Cuenca's talk including non-SM Higgs results

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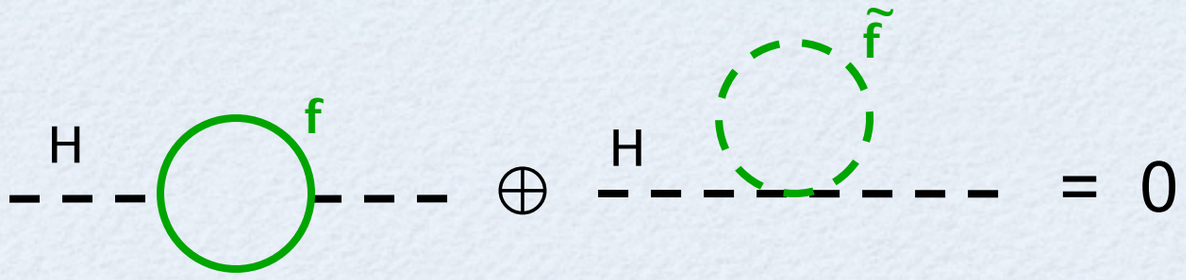
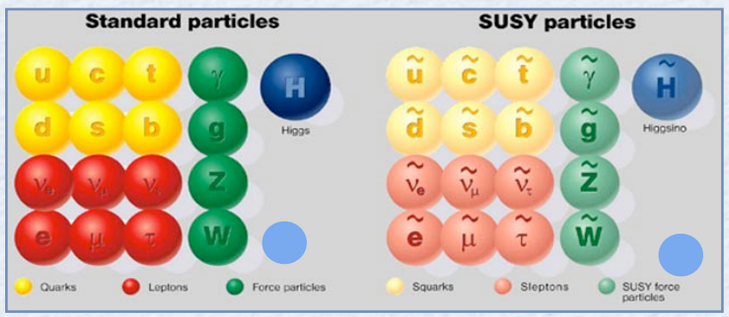
Supersymmetry

$$Q|\text{boson}\rangle = |\text{fermion}\rangle$$
$$Q|\text{fermion}\rangle = |\text{boson}\rangle$$



Exact cancellation between fermion and boson loops for higgs

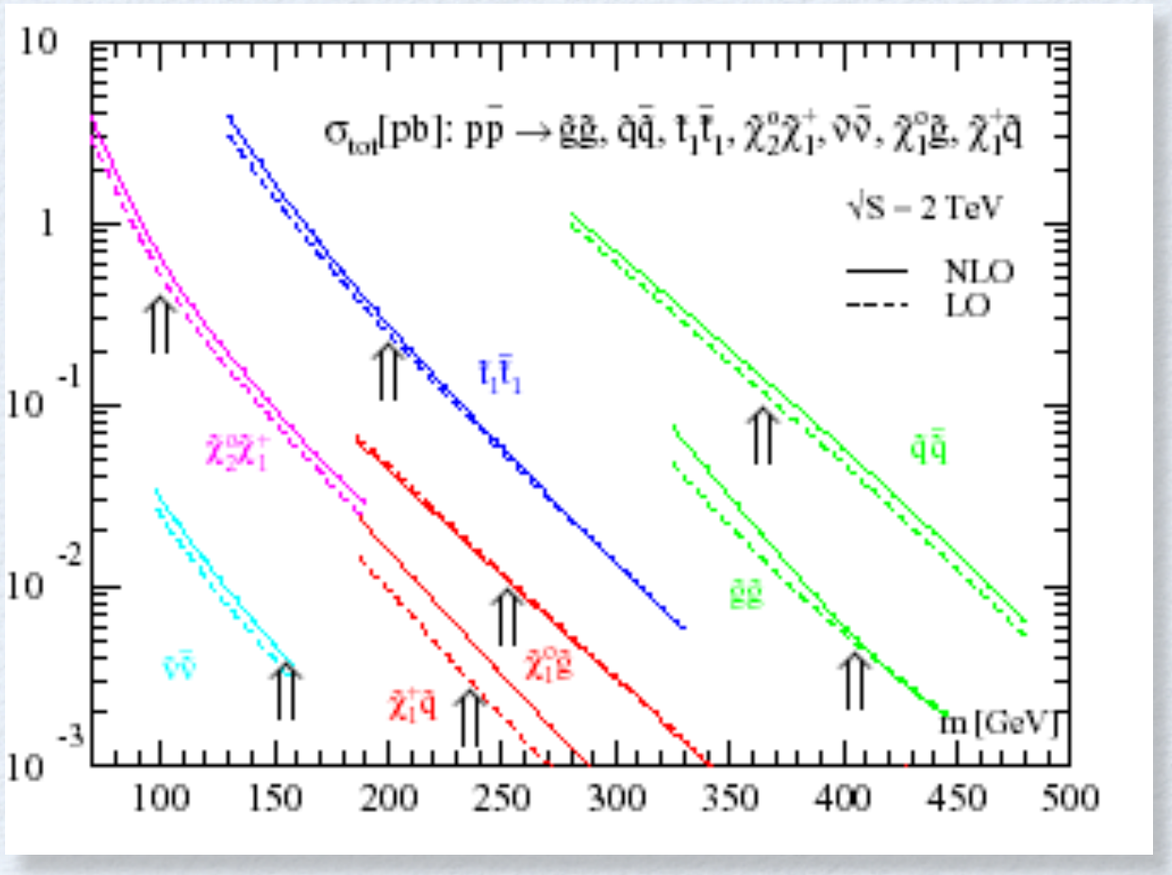
- Elegant solution to hierarchy problem
- Pay the price: 2 times more particles



SUSY must be broken ⇒ model dependent phenomenology:

✓ could provide strong dark matter candidate

✓ also good framework for unification of forces



Cross Sections for SUSY processes at the Tevatron

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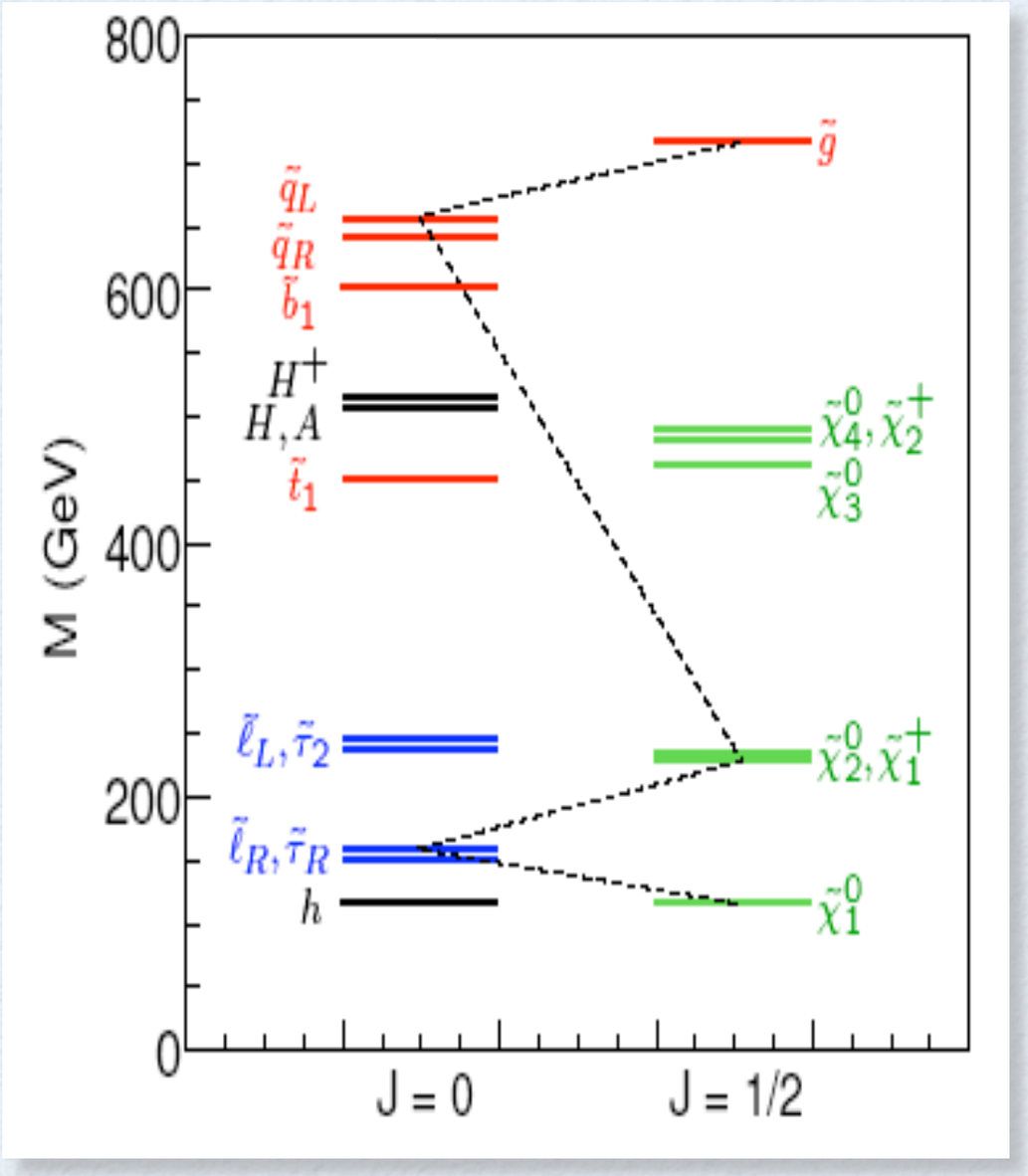
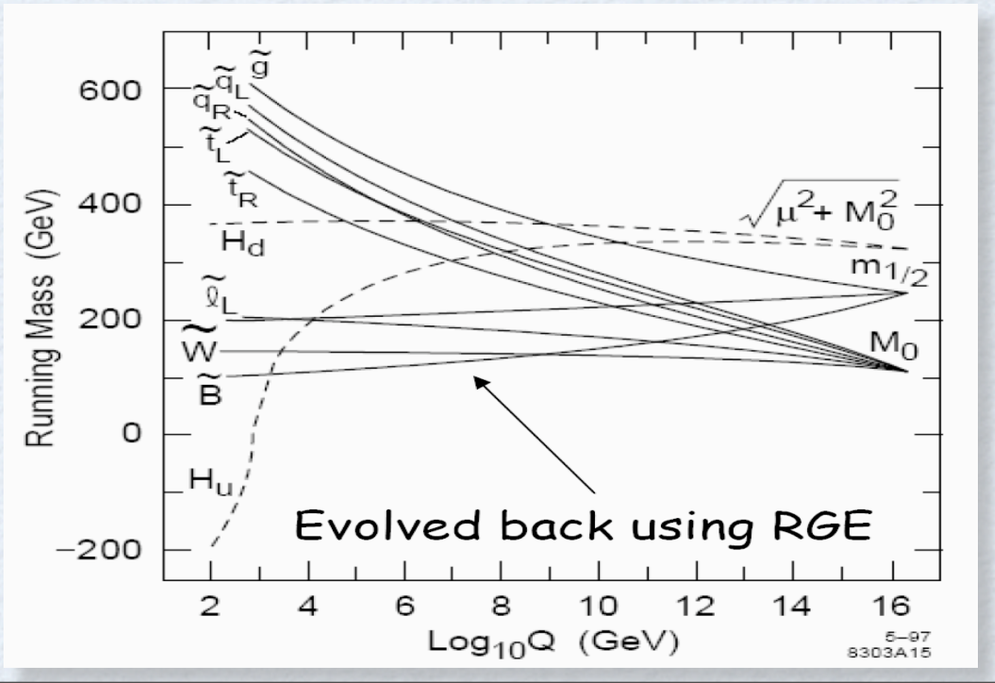
mSUGRA framework



Typical mSUGRA spectra

- SUSY breaking is gravity mediated.
- Only five free parameters (MSSM has >100): M_0, $M_{1/2}$, tanβ, A_0, sign(μ).
- Masses unified at GUT scale: TeV spectrum derived with RGEs.
- Squarks and gluinos heaviest, neutralino is the LSP.
- R-Parity conserved: sparticles produced in pairs, LSP is stable.
- Typical signature at colliders: large transverse energies and large $\not\!\!E_T$.



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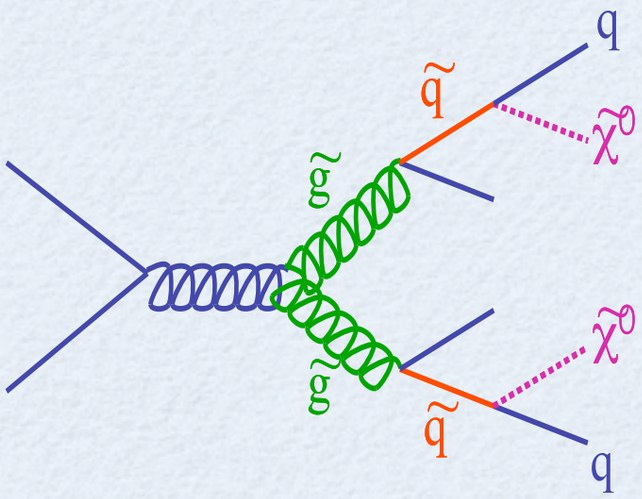
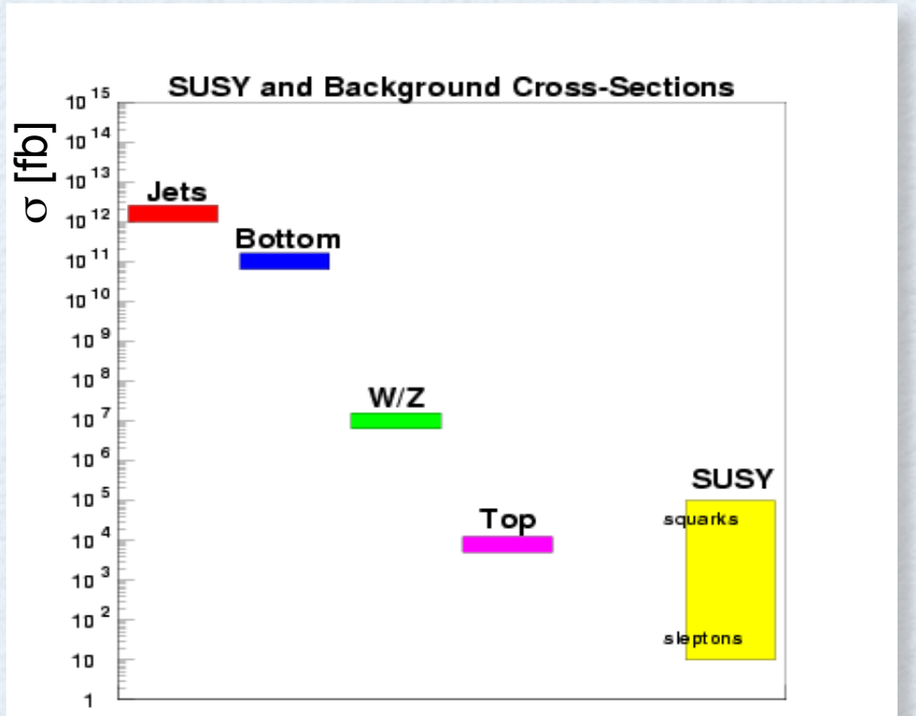
Inclusive search for $\tilde{g}/\tilde{q}$ (1)

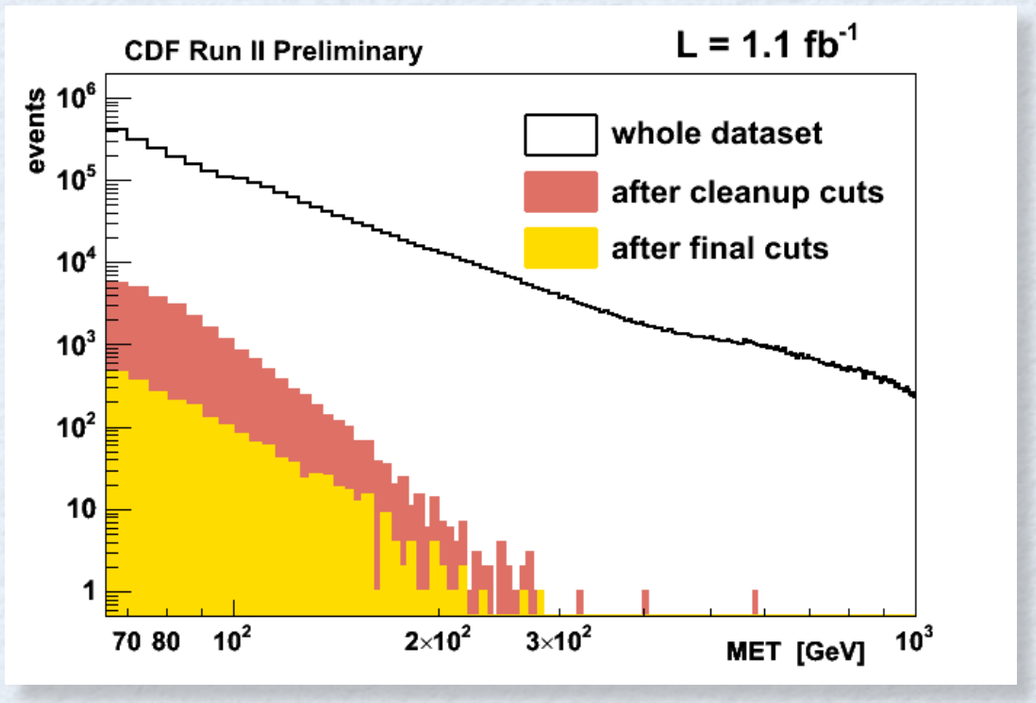
$2\,fb^{-1}$



- ✓ Pair production of gluinos and squarks
- ✓ mSUGRA signature with energetic jets of hadrons and large $\not\!\!E_T$ ($\tilde{\chi}^o$)



- Difficult search: <u>huge background reduction required</u>
  - Beam-gas and cosmics contamination reduced with basic clean-up cuts
  - QCD and W/Z+jets production
  - Irreducible top and $Z\rightarrow\nu\nu$ background
- Specific cuts for SM background reduction
- SM background estimated from Monte Carlo



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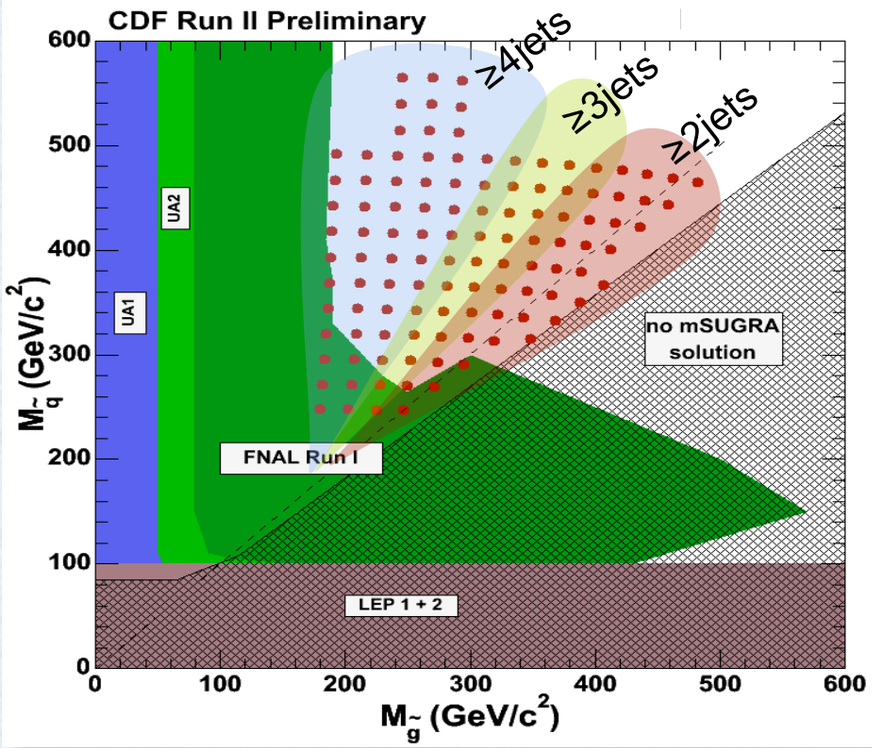
Inclusive search for $\tilde{g}/\tilde{q}$ (II)

$2\,fb^{-1}$



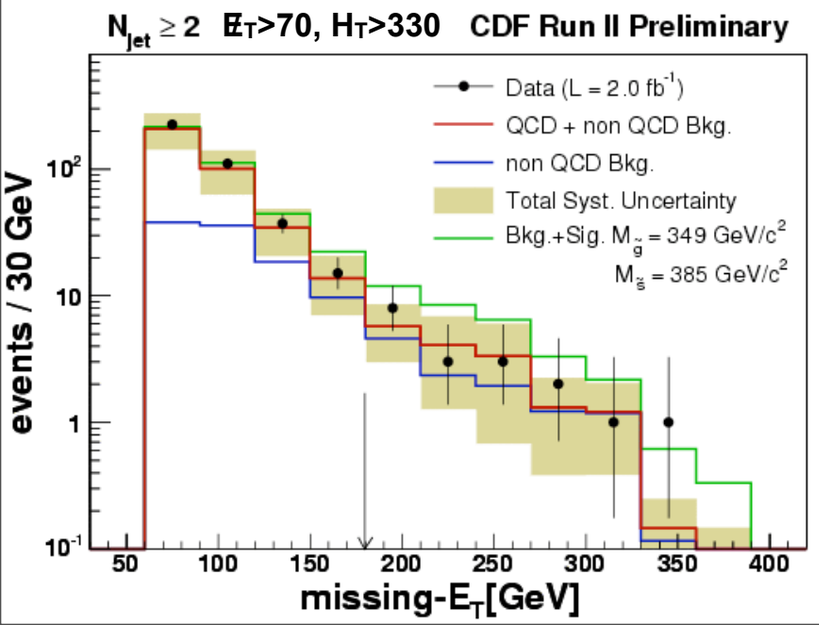
- mSUGRA scenario with $A_0=0$, $\tan\beta=5$ and sign(μ)<0.
- Scan across $M_{\tilde{g}}/M_{\tilde{q}}$ plane via variation of M_0 and $M_{1/2}$
- Jet multiplicity depends on $M_{\tilde{g}}$ and $M_{\tilde{q}}$:

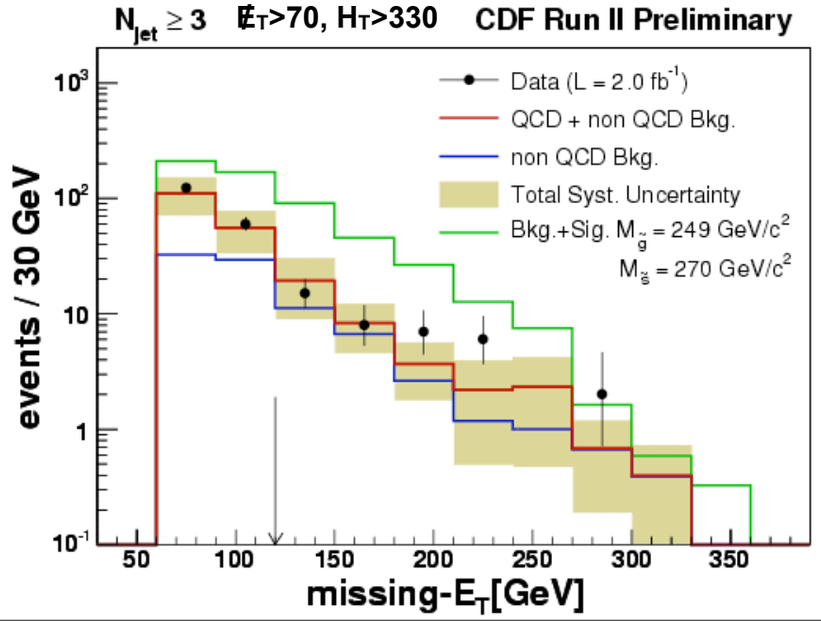
3 analyses developed for best sensitivity

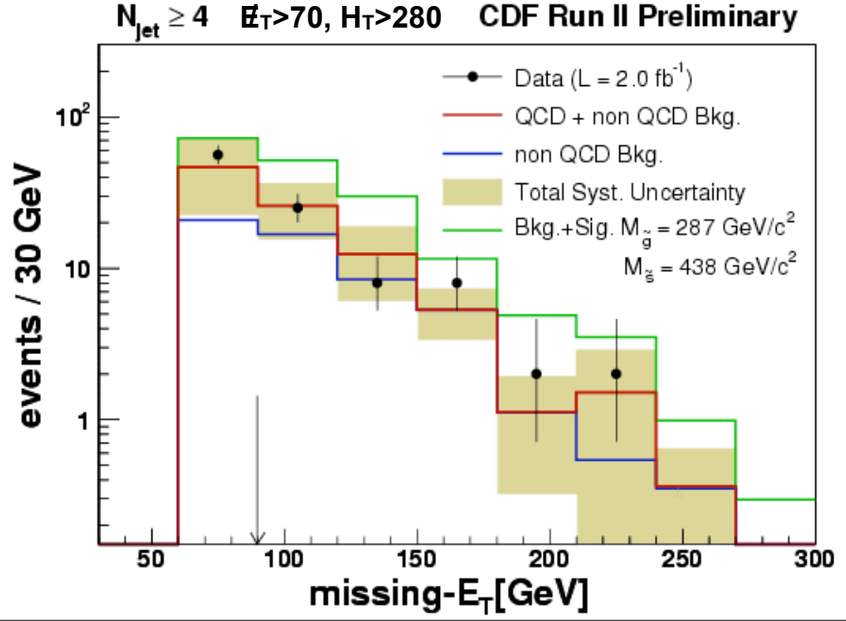
- At least 2, 3 or 4 jets required in the final state
- Selection optimized using $\not\!\!E_T$, E_T(jets) and $H_T=\Sigma E_T$(jets)

events in 2.0 fb^{-1}	DATA	SM Expected
≥ 4 jets	45	48 ± 17
≥ 3 jets	38	37 ± 12
≥ 2 jets	18	16 ± 5

Good agreement DATA - SM







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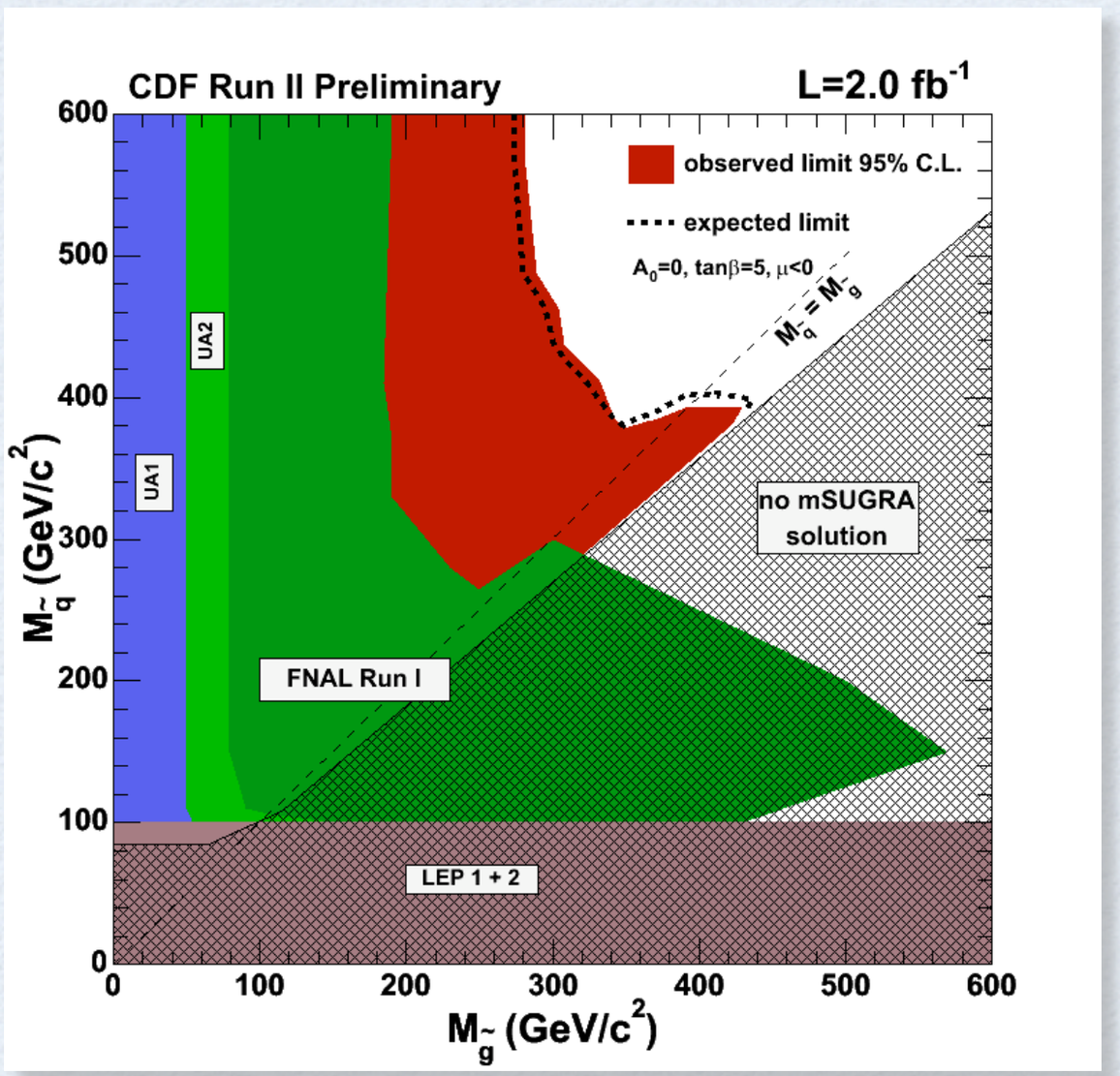
Inclusive search for $\tilde{g}/\tilde{q}$ (III)

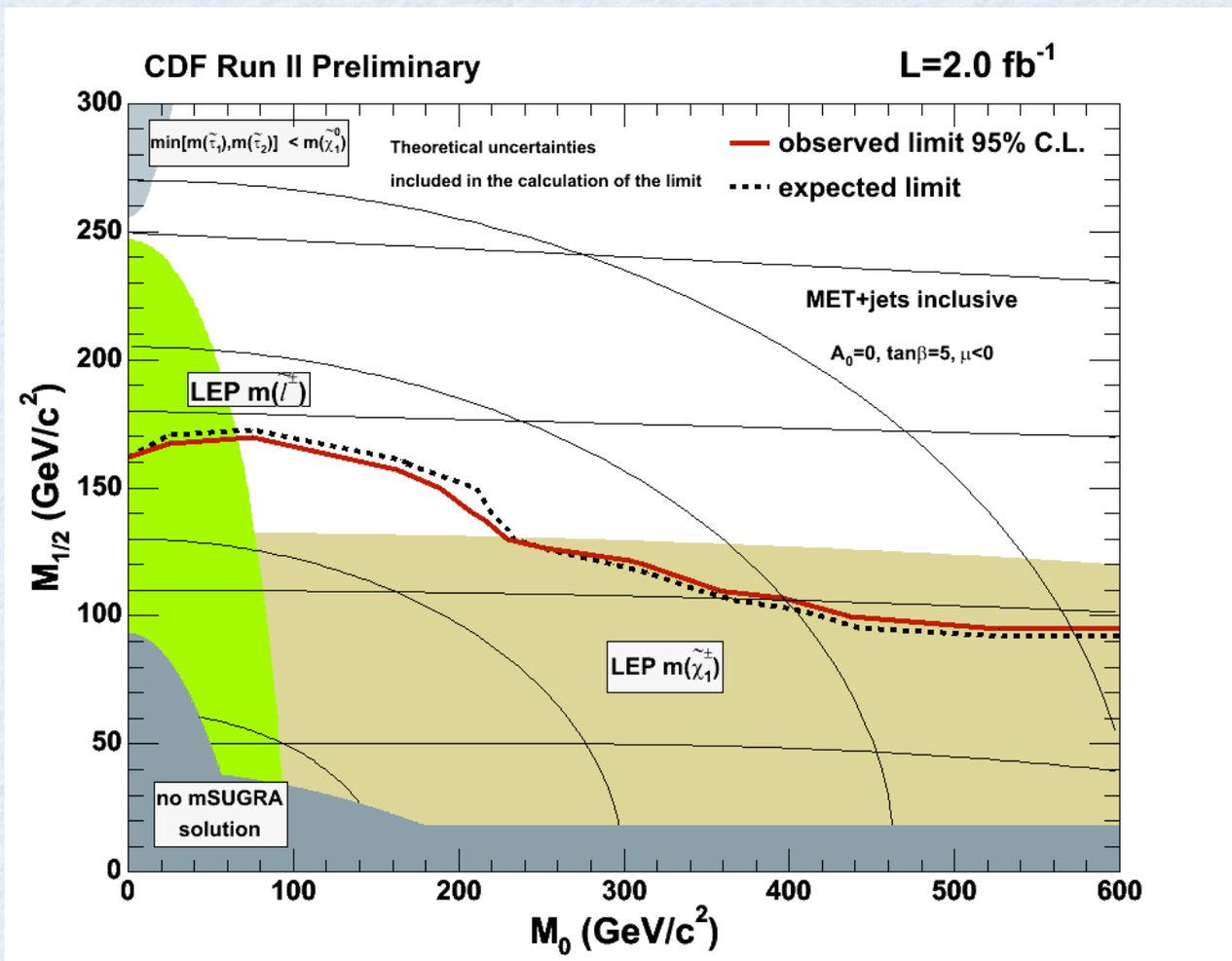
2 fb^{-1}

95% C.L. Exclusion limit on $M_{\tilde{g}}M_{\tilde{q}}$ and $M_0M_{1/2}$ planes

- When $M_{\tilde{g}}=M_{\tilde{q}} \rightarrow$ **M > 392** GeV/c^2
- **$M_{\tilde{g}}$ < 280** GeV/c^2 excluded in any case



- LEP limit improved in the region where **75<M_0<250** and **130<$M_{1/2}$<170 GeV/c^2**



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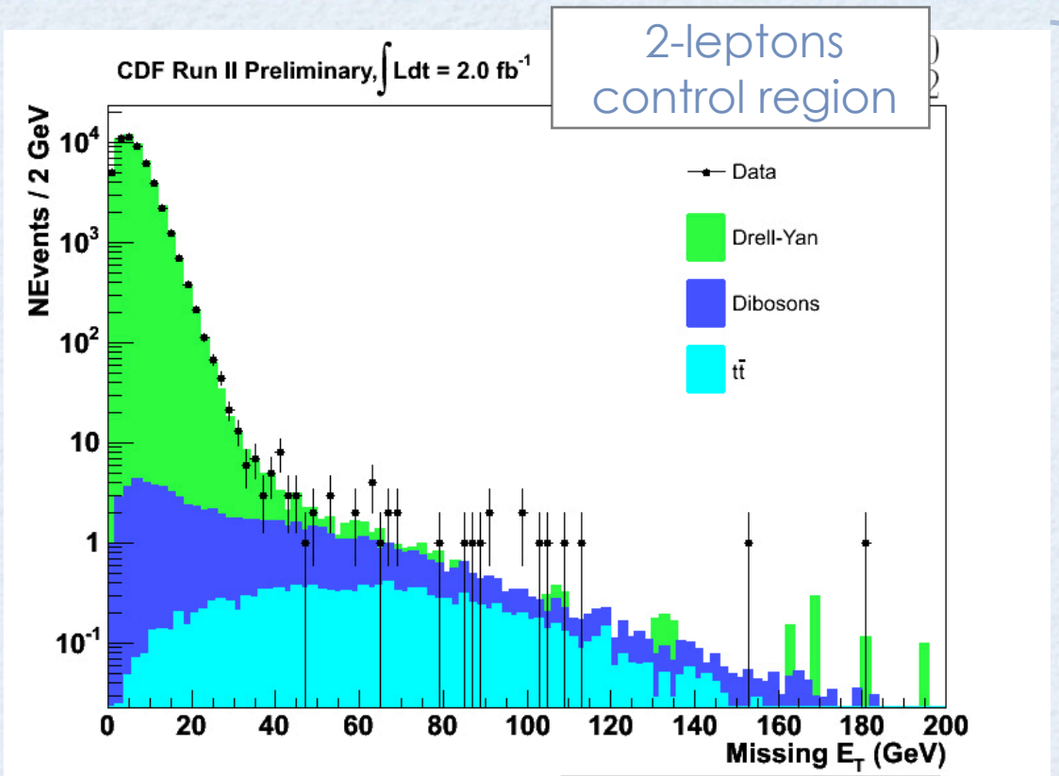
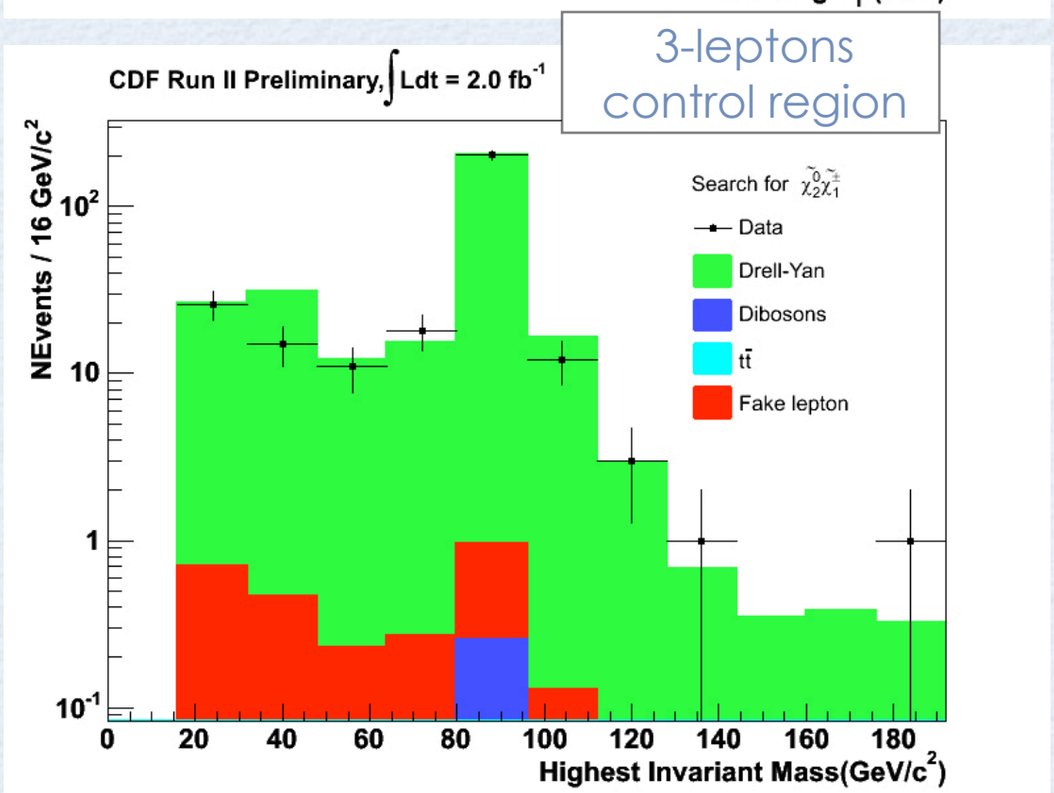
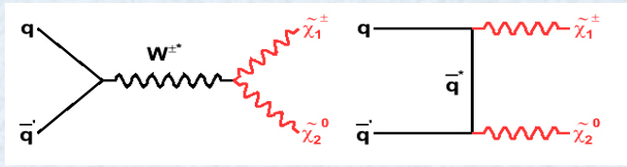
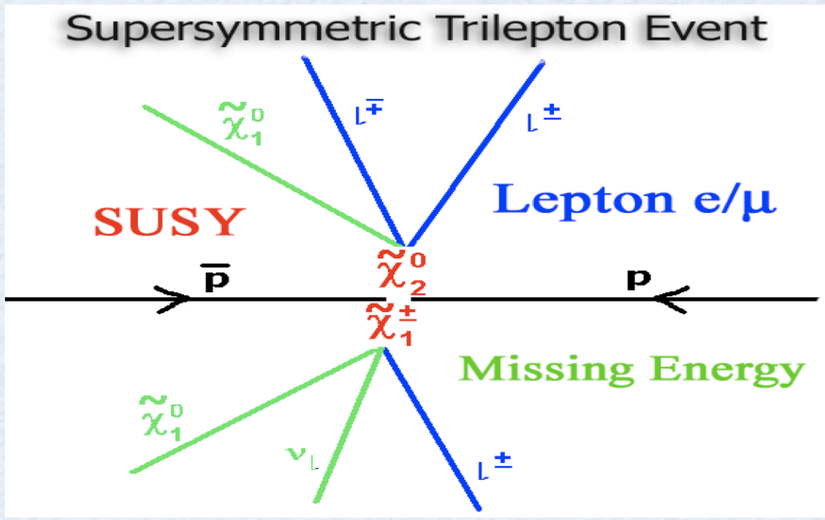
$\tilde{\chi}_2^0\tilde{\chi}_1^\pm$ in trilepton events (I)

2fb^{-1}









- mSUGRA associated $\tilde{\chi}^0\tilde{\chi}^\pm$ production.
- Signature is 3 leptons + $\not\!\!E_T$
- Multiple SM backgrounds (MC estimated):
  - 3 real leptons: $t\bar{t}$, WZ and ZZ
  - 2 real leptons + fake: DY, WW, W+jets
- 5 exclusive channels with 3-leptons or 2-leptons+iso-track selections
- Large number of control regions defined to check Monte Carlo samples

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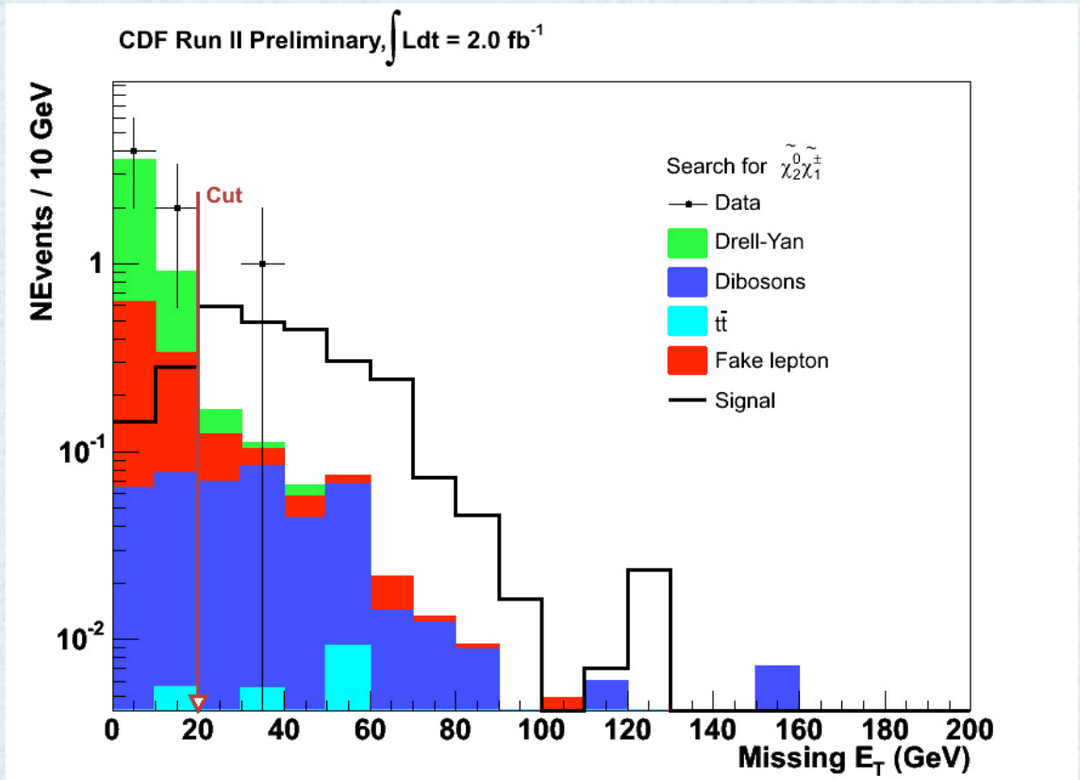
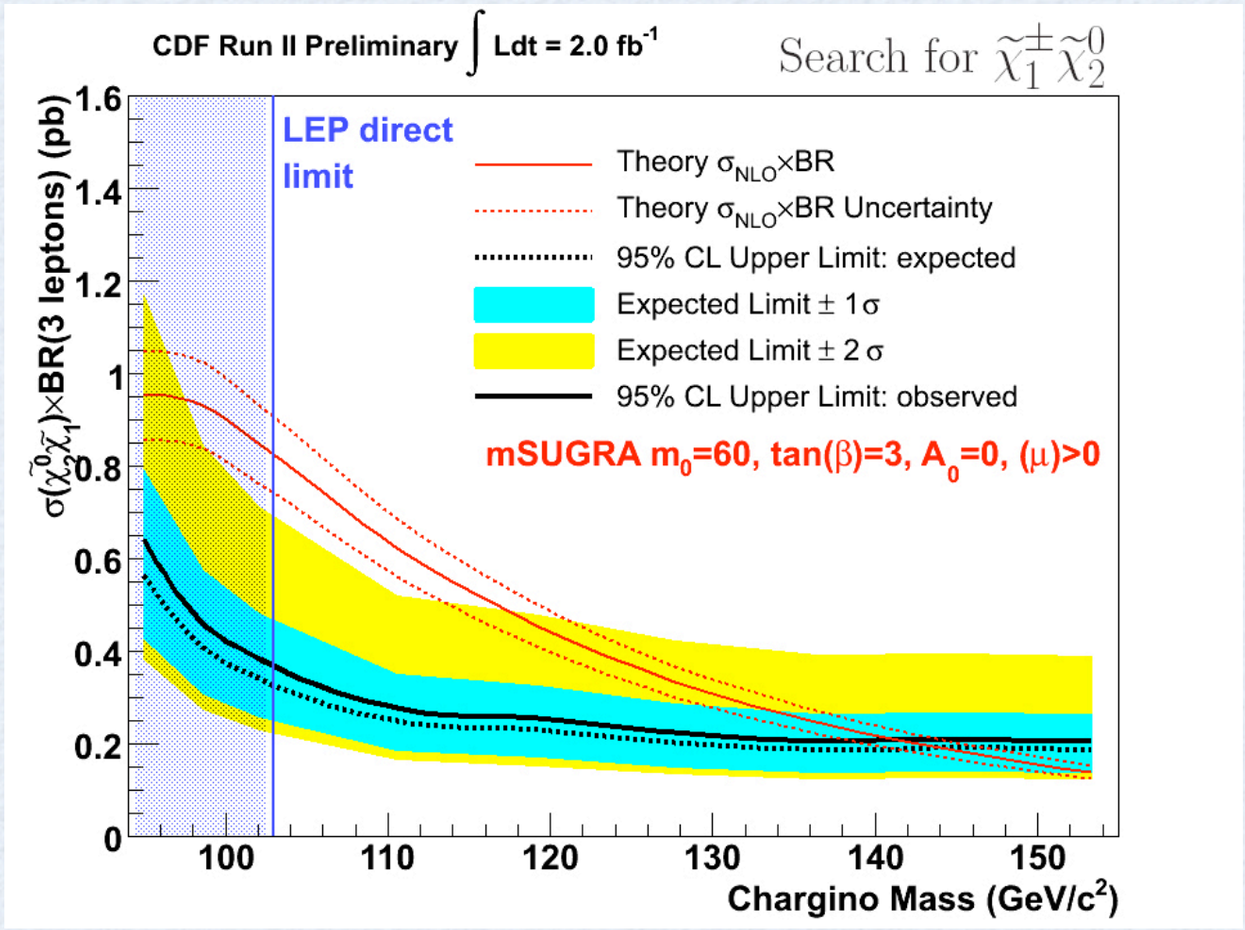
$\tilde{\chi}_2^0\tilde{\chi}_1^\pm$ in trilepton events (II)

2 fb^{-1}

channel	DATA	SM Expected
trilepton (3 channels)	1	0.88 ± 0.05 ± 0.13
dilepton + track (2 channels)	6	5.5 ± 0.7 ± 0.9





- Good agreement between SM and DATA in the five signal regions
- Limit on mSUGRA chargino mass has been extracted combining five signal regions:

  $M(\tilde{\chi}^0) > 140$ GeV/c^2

- ➧ LEP direct limit improved.

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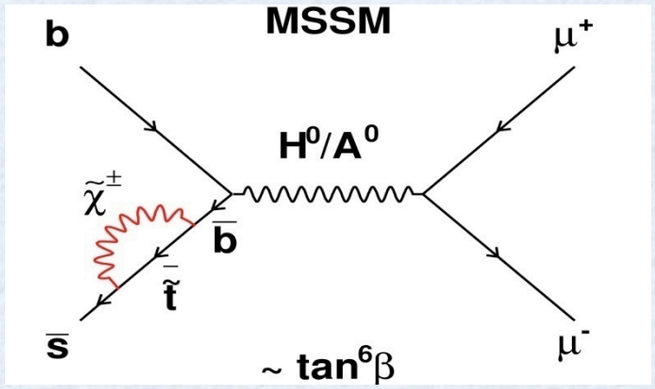
$B_s \to \mu^+\mu^-$ decays (1)

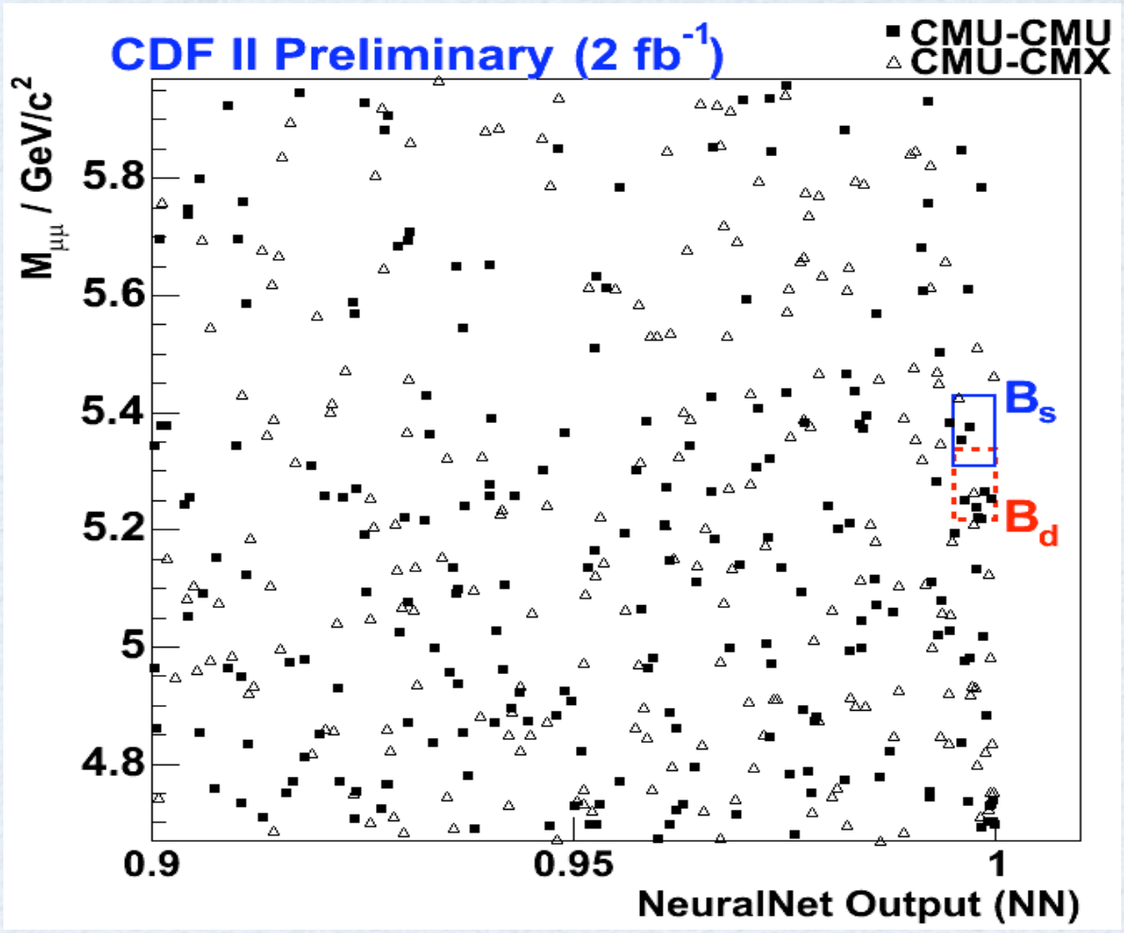
2fb^{-1}

Sensitive to new physics: if no observation
⇒ can strongly constrain SUSY models



SM prediction:
BR = 3.42×10^{-9}

SUSY enhancement
$\propto (\tan\beta)^6$



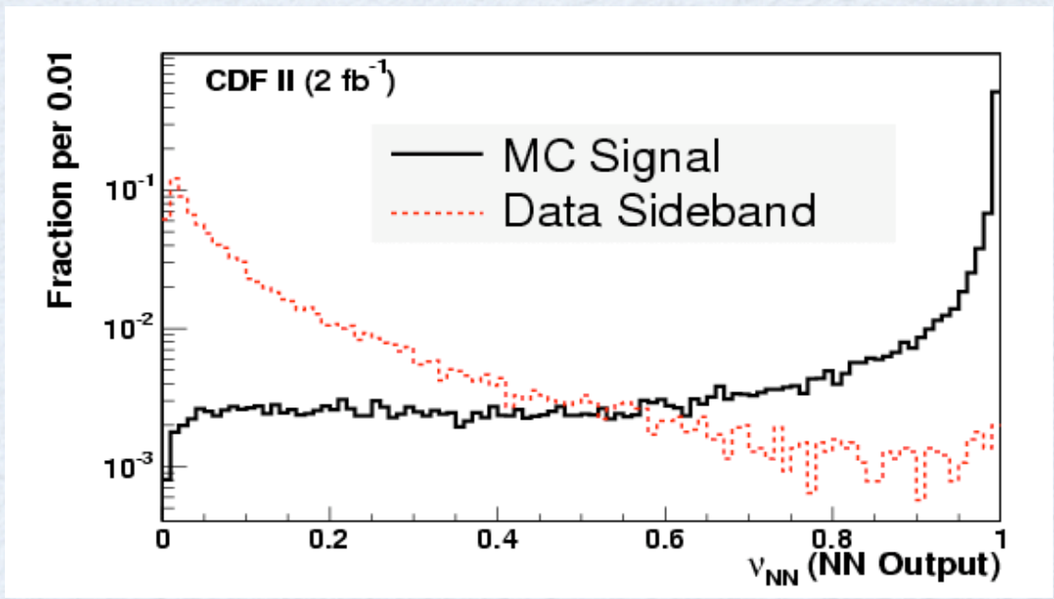
- Data sample dominated by random combinatorial background
- Extract signal with Neural Net based discriminant

B_s and B_d considered separately:

$B_s \to \mu\mu$ 3 observed events (3.6+/-0.3 exp.bkg.)

$B_d \to \mu\mu$ 6 observed events (4.3+/-0.3 exp.bkg.)

No significant excess ⇒ exclusion limit



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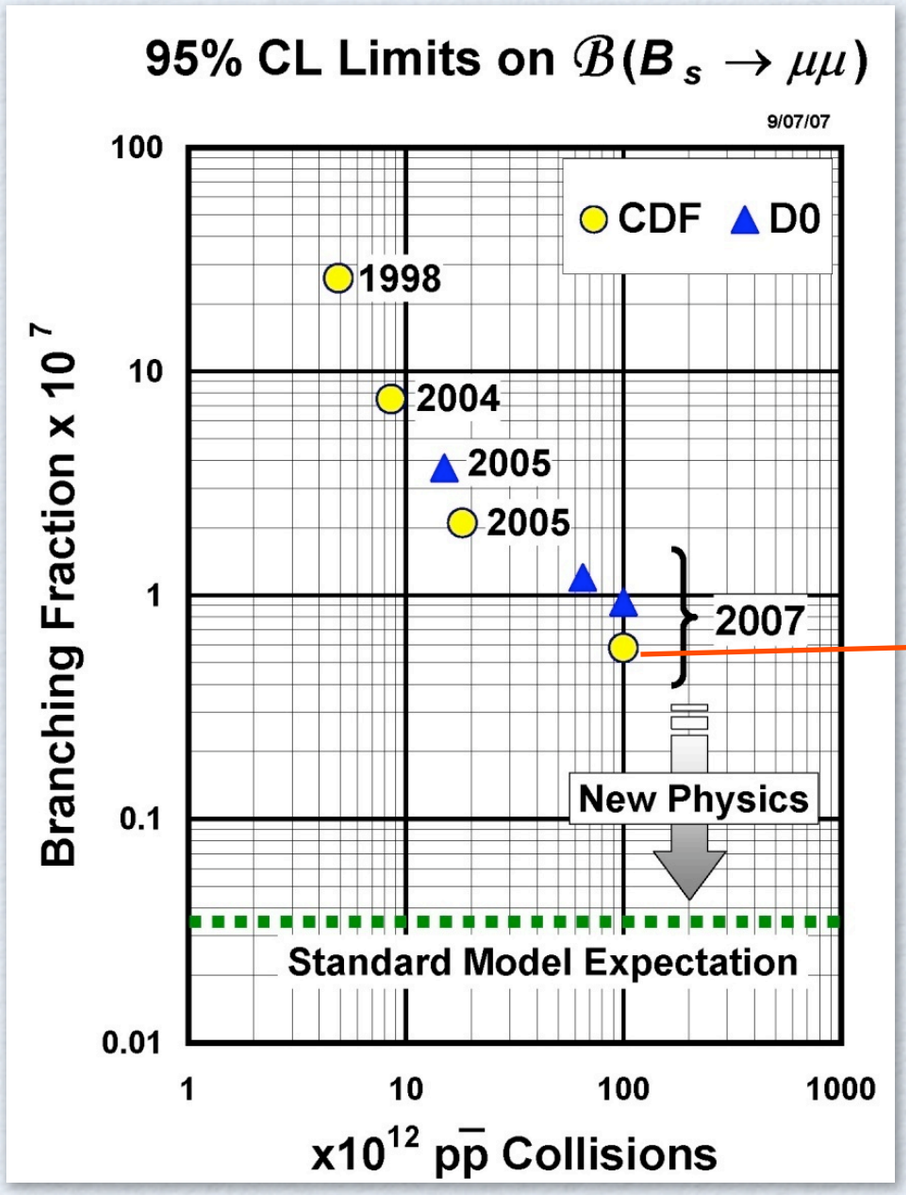
$B_s \to \mu^+\mu^-$ decays (II)

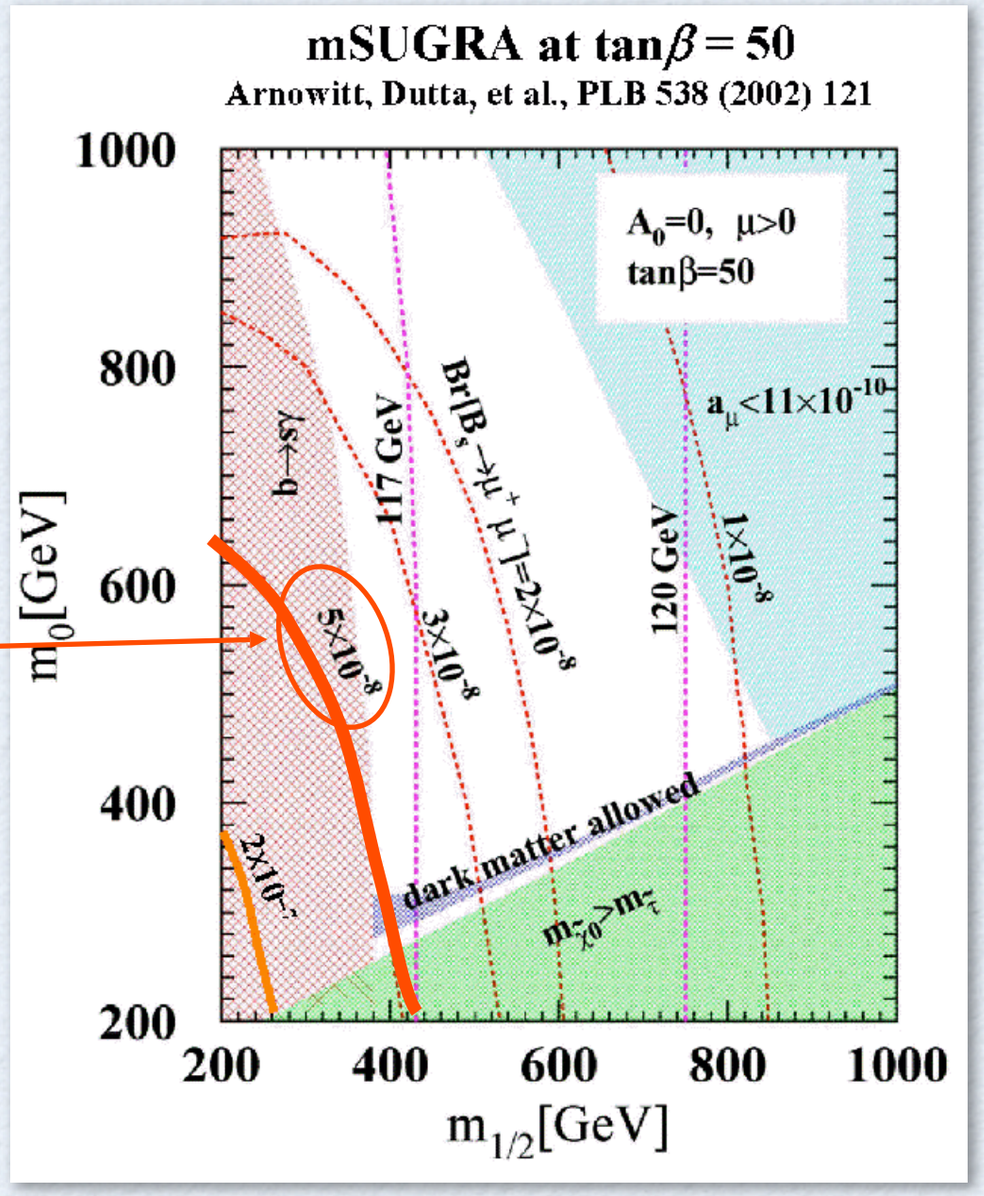
$2fb^{-1}$

$Br(B_s \to \mu\mu) < 5.8 \times 10^{-8}$ @ 95% CL

$Br(B_d \to \mu\mu) < 1.8 \times 10^{-8}$ @ 95% CL

Constraints on mSUGRA plane





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jet + $\not\!\!E_T$ and γ + $\not\!\!E_T$

2 fb^{-1}

Compactified Large Extra Dimension models (LED) predict direct production of Gravitons:

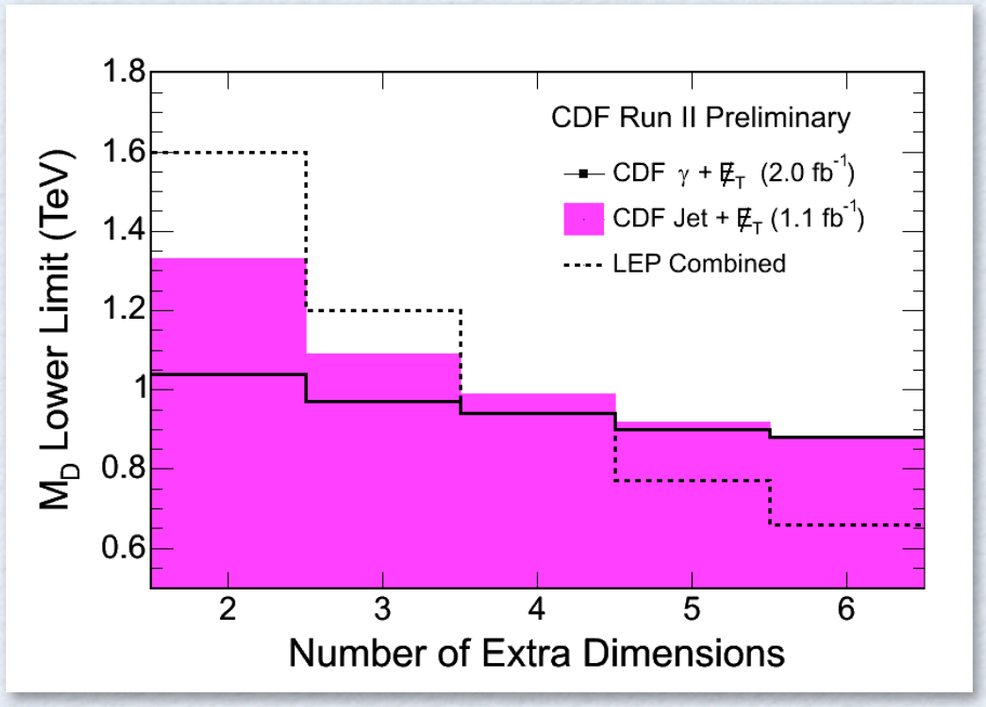
jet+$\not\!\!E_T$

$q\bar{q} \to gG_{KK}$, $qg \to qG_{KK}$, $gg \to gG_{KK}$

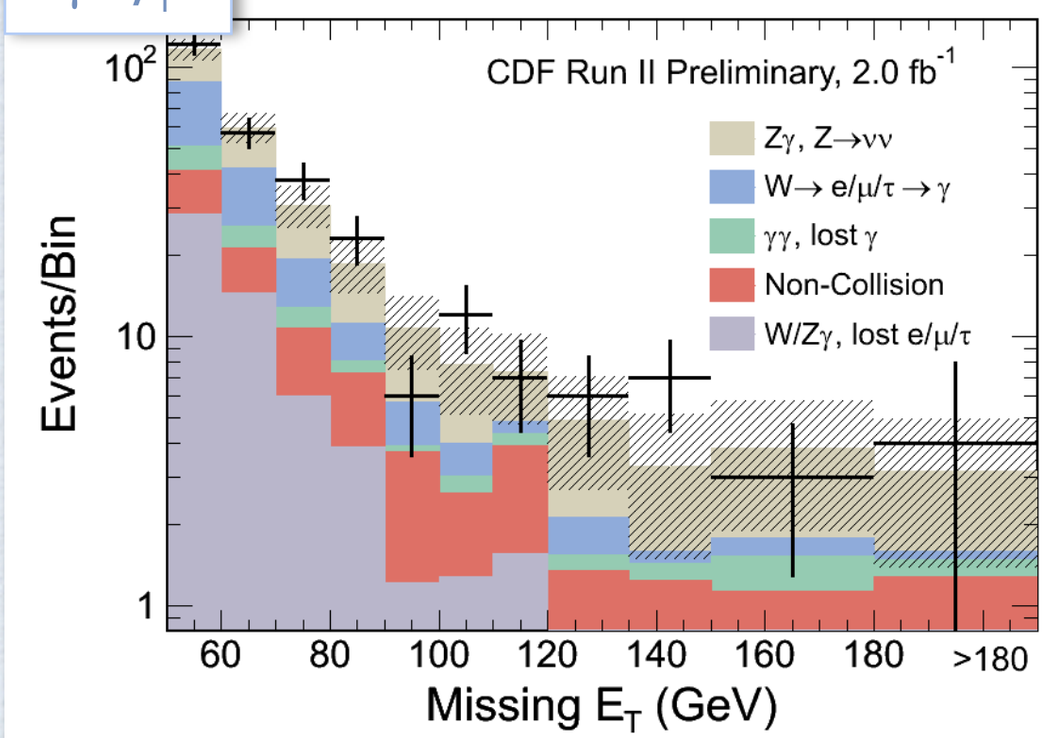
$q\bar{q} \to \gamma G_{KK}$ γ+$\not\!\!E_T$

- G_{KK} would leave the detector unobserved: signature with large $\not\!\!E_T$.
- CDF observes no excess with respect to the SM

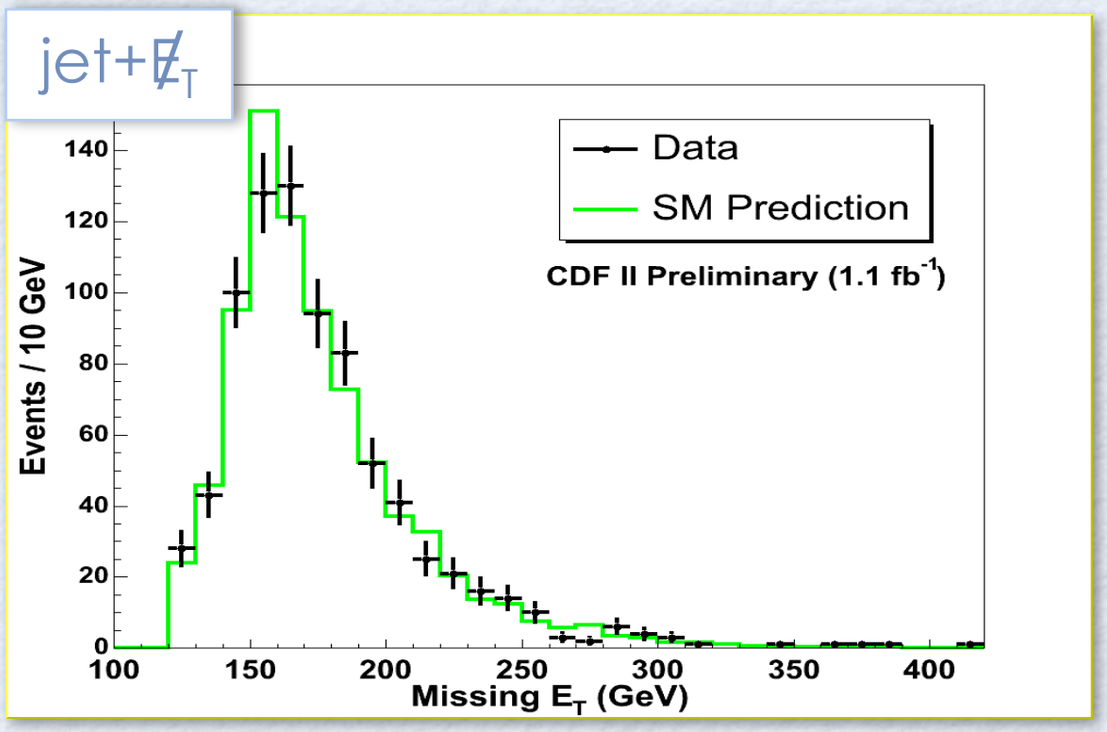
⇒ limits on LED fundamental mass scale (M_D)



γ+$\not\!\!E_T$



jet+$\not\!\!E_T$



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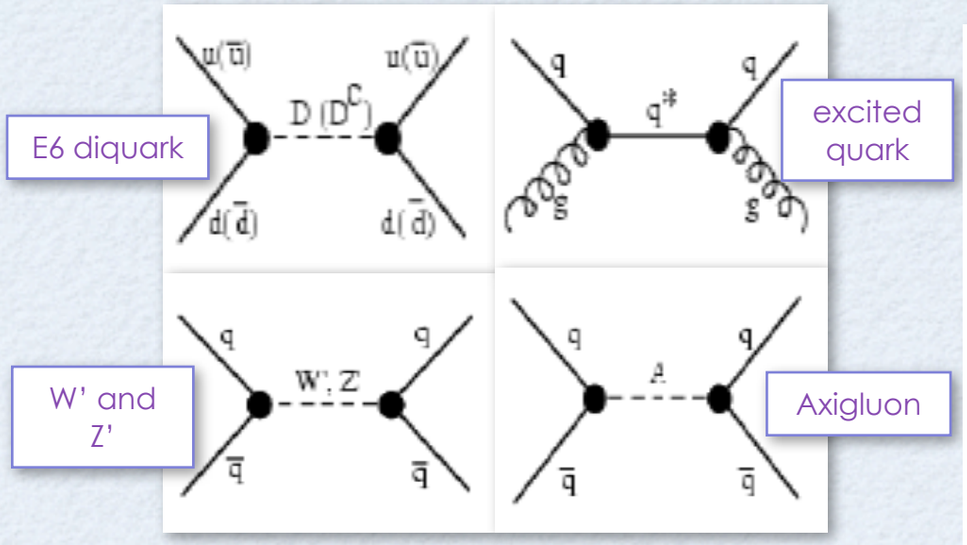
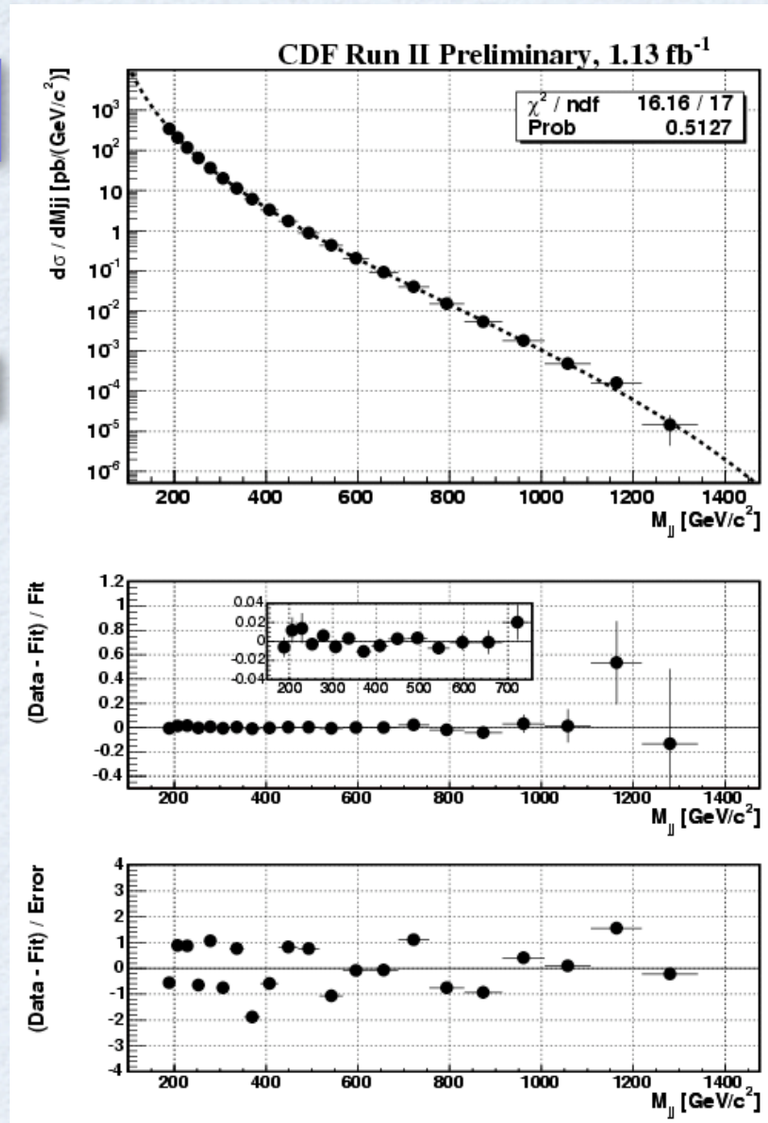
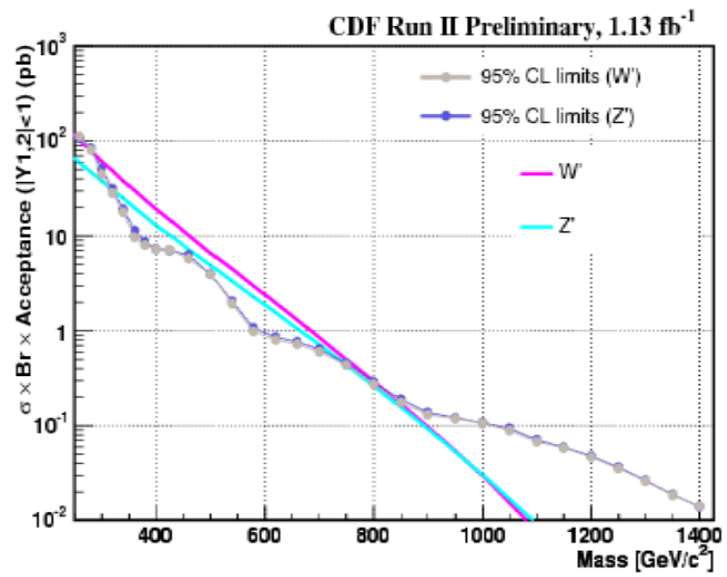
Dijet mass resonance search

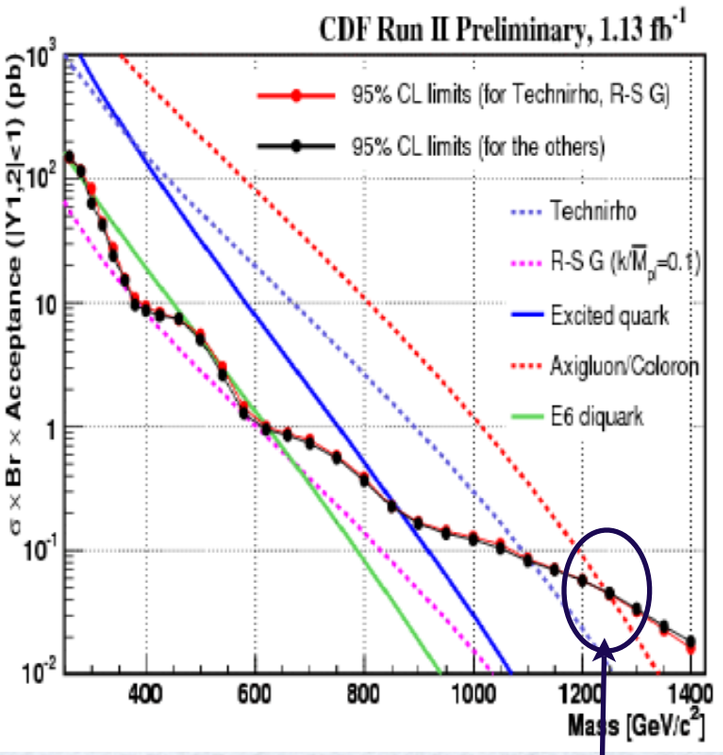


- Dijet mass spectrum sensitive to new high mass particles decaying into dijets.
- Large QCD background estimated from data.

• search for resonances by fitting the measured dijet mass.
• no resonance found ⇒ set <u>upper limits on new particle production cross sections</u>.







Some excluded mass windows:
Excited quark m = 260 - 870 GeV
Color-octet technirho m = 260 - 1110 GeV
Axigluon m = 260 - 1250 GeV
E_6 diquark m = 260 - 630 GeV

exclusions up to 1.25 TeV

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$\gamma\gamma + \not\!\!E_T$ and $\gamma\gamma + \tau$

$2\,fb^{-1}$

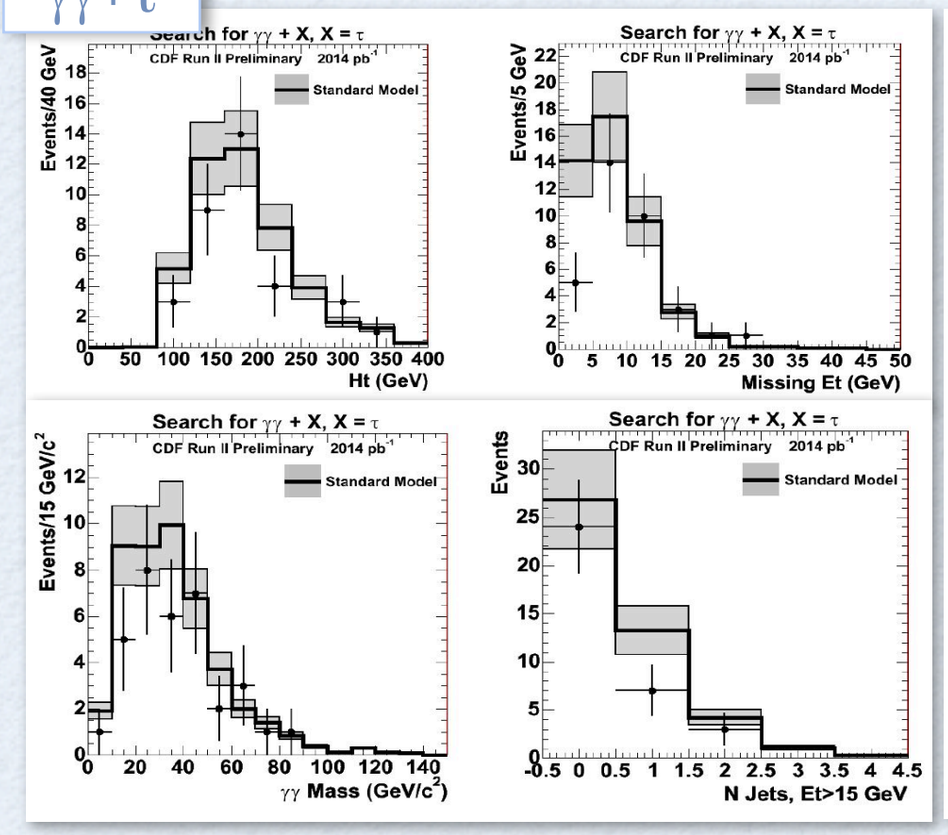
signature based search:

- ✓Sensitive to wide range of new physics models
- ✓High integrated luminosity
  - $\gamma\gamma+\tau$ with 2.0 fb^{-1}
  - $\gamma\gamma+\not\!\!E_T$ with 1.2 fb^{-1} (2 fb^{-1} update expected soon)
- ✓Backgrounds estimated from data.

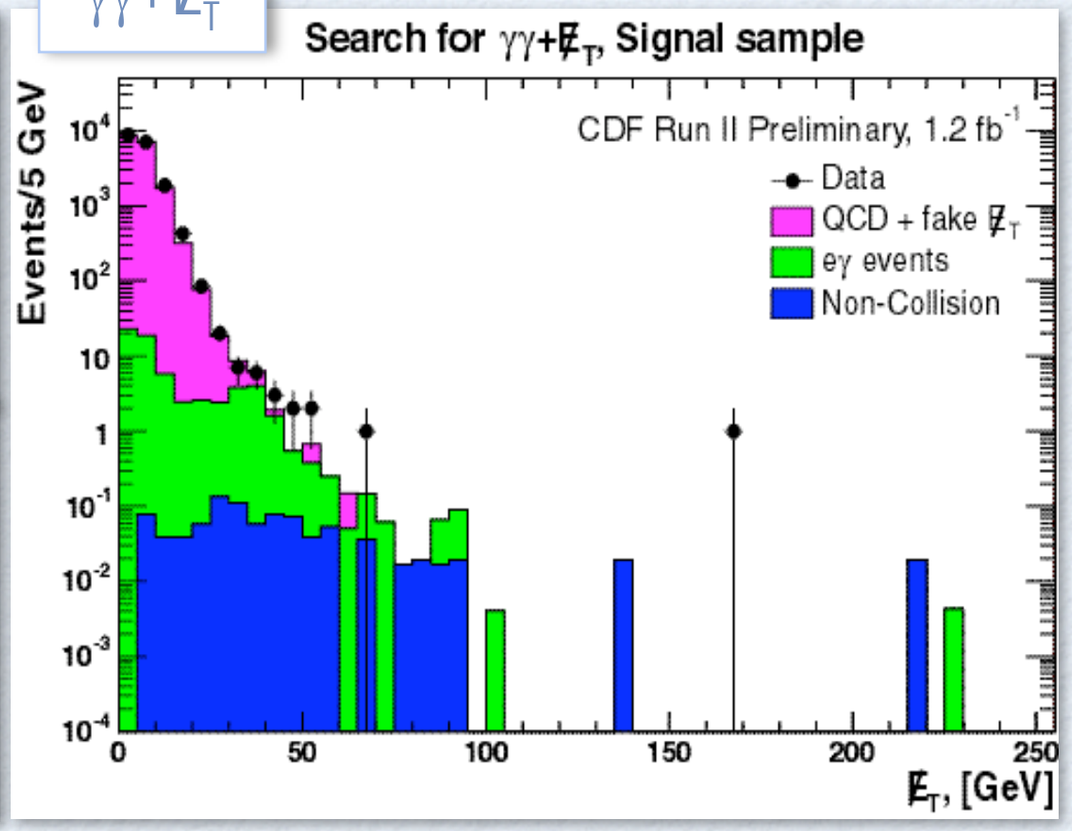
many models of new physics with diphoton final state:

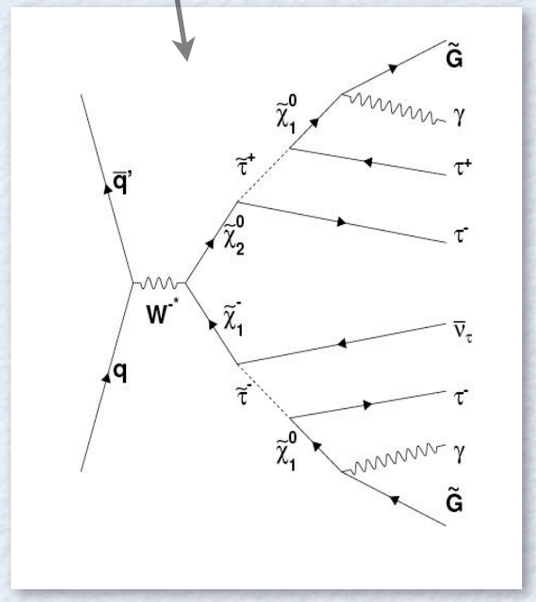
- fermiphobic Higgs
- $\chi^2 \rightarrow \gamma\chi^1$
- $\tilde{b}$` pairs
- GMSB
- ...

$\gamma\gamma+\tau$



$\gamma\gamma+\not\!\!E_T$

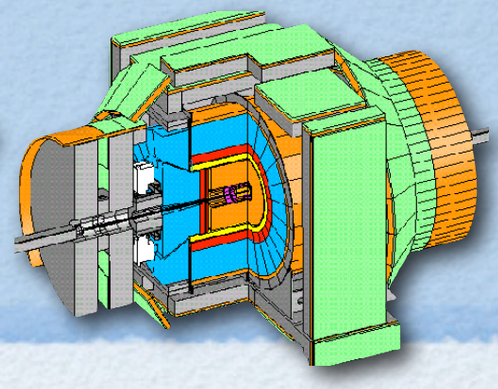




example of GMSB

Good agreement DATA - SM

Summary



- CDF has a wide and exciting program of searches for physics beyond the Standard Model.
- Results with 2 fb^{-1} of DATA have been presented.
  - SUSY searches
  - extra-dimension searches
  - signature based searches
  - resonances
  - …
- No evidence of new physics yet…

  Tevatron will deliver 7 fb^{-1} by the end of Run II

  LHC scheduled to start operations this year

Discovery of new physics could be just around the corner